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KEY ISSUES AND MANAGEMENT STRATEGIES FOR THE CONSERVATION OF THE HIMALAYAN TERAI FORESTS OF INDIA

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Abstract

The Himalayan Terai forests are the major habitat for a variety of terrestrial biodiversity, with distinct extents of ecosystems, abundance and distribution of species and coverage of protected areas. This lowland region is mainly characterised by tall grasslands, scrub savannah, Sal forests, wetlands, and swamps. The Terai eco-region, shared by India and Nepal, is one of the prominent areas of India from a biodiversity point of view. It is situated along the foothills of the central Himalaya, in the north of the Indo-Gangetic Plain, with a forest covers of ca. 10,000 km^2 in India. The Terai eco-region contains dense forests, savannahs and grasslands, providing critical habitats for many endangered large mammals, including tigers, elephants and rhinoceroses. Currently, the forest of this region is losing its biodiversity because of natural and anthropogenic factors. Because of the high agricultural productivity of the Terai areas, rising aspirations for better living conditions, development activities, industries and road & rail networks, the degradation and fragmentation of these forests have increased in recent years. This paper presents key issues and management strategies for the conservation of the Himalayan Terai forests of India, along with some suggestions to overcome the impacts of natural and anthropogenic disturbances.

Keywords*: Natural disturbances; Anthropogenic disturbances; Conservation management; Himalayan Terai*

Introduction

India is a land of diversity with twelve biogeographical regions: Trans Himalaya, West Himalaya, East Himalaya, North East India, The Indian Deserts, Semi Arid Zone, Gangetic Plain, Western Ghats, Deccan peninsula, Indian Coasts Andaman and Nicobar Islands and Lakshadweep Islands [1]. The Gangetic Plain is a flat region made up of alluvial soils by Ganga and its tributaries. This geographical region has two types of forests: i) Tropical moist deciduous forests and ii) Tropical dry deciduous forests. The tropical moist deciduous type of forests is present in the Terai eco-region only. Terai inclusively harbours North Indian tropical moist deciduous forest. This is because it is an ecotone between the Gangetic plains and Himalayan foothills, it becomes one of the diverse areas of the country from biodiversity point of view [2-4]. The entire eco-region had unique natural Sal forests and was the home of good

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faunal diversity [5-7]. But now the forest of this region is losing its biodiversity at alarming rate because of natural (floods, global warming) as well as anthropogenic (logging, looping, grazing, agriculture penetration, human settlement) disturbances and therefore, the forest cover has become severely fragmented into some protected forests only [8-11]. These protected forests are either national parks (Rajaji, Jim Corbett, Dudhwa and Valmiki) and wildlife sanctuaries (Kishanpur, Katerniaghat, Suhelwa, Parvati Arga, Bakhira, Sohagi Barwa) or reserve forests (Pilibhit tiger reserve). All these protected forest areas are surrounded by human settlements and even sometimes these settlements are available within the territory of the forests, specifically in the buffer zone [12]. This surrounding human population majorly depends on the forests for several forests products such as wild fruits, root vegetables, mushroom, fodder, firewood and timber [13-16]. Besides these direct services, the forests are also serving the society and environment by some other indirect benefits such as, catchment protection [16-18] flood control [19-22], ground water recharge [23-25], sequestration of ambient carbon [26-29], soil protection and enrichment through nutrients fixing & cycling [30-38] as well as generation of revenue by way of tourism [39]. Hence, the forests of Terai eco-region are very important, not only for the ecological point of view but also for the sociological and economical aspects.

The natural disturbances influence the biodiversity through forest fire, landslides, floods, river banks cutting and extreme weather event, as they alter habitat conditions as well as the population dynamics of forest species [10, 40]. The successional stages and the effectiveness of these disturbances shape the heterogeneity and biodiversity of a forest [41-45]. The Terai forests are intersected by both perennial and seasonal rivers exhibiting seasonal high and low flows. The deposition of sediments by rivers and streams creates several channels within the Terai region with shallow beds. This augments the impacts of periodic floods when monsoon-swollen rivers overflow their low banks and shifts channels. Many areas show high erosion such as gullies that also affect the abundance and distribution of species. Degradation of key watersheds has also led to soil erosion and low water tables that have affected the population dynamics of forest species. The Himalayan Terai eco-region consists of the natural forests as well as a human-dominated landscape with some of the most fertile agricultural lands supporting millions of people dependent on agriculture and natural resources for their livelihoods. Because of the increasing human settlements and economic activities, such as logging, looping, grazing, agriculture intensity, industries and road & rail networks, the degradation and fragmentation of these forests have increased. These factors are triggering the changes in forest structure and dynamics [46, 47]. Midha and Mathur [22] also cite activities such as clear cutting, development of rail and road network, and plantations as the cause of fragmentation of habitats in the Terai ecosystem. This large-scale human interference in the forests actually enhances the effects of such disturbances and their frequency [48, 49]. Anthropogenic activities in many cases cause impacts on the forest health of forests by, reduction in biodiversity, species richness, regeneration percentage and forest community composition [50, 51]. Human activities further accelerate harvesting of useful plants [52-54], lopping plants for fodder [55, 56], uncontrolled grazing [57-59], soil destruction [57, 60], forest fragmentation [61, 62], invasion of alien species [63, 64], loss of native vegetation [65, 66] etc. These are not only the problems of unprotected forests but also of the lawfully declared protected areas by pressure from encroachments, especially near the human settlements [67-69]. The combined effects of natural and anthropogenic perturbations have led an emergent need of implementing restoration and management strategies at regional, national and global level [63, 70-72].

As per Society for Ecological Restoration International, Science and Policy Working Group [73], restoration is a process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. It also helps in the re-introduction and re-establishment of native communities (a group of associated species for a specific area) in their habitats [74]. The enhancement and acceleration of natural processes of forest regeneration for the reestablishment

of healthy forests as well as improvement in the environmental quality are the main objectives of the forests restoration strategies [75, 76]. For a better and feasible restoration management strategy, it is important to study all three main domains *viz*., social (community structure, benefits sharing, traditional knowledge, empowerment and awareness), ecological (species diversity, site-specific habitats, phytosociological status, environmental condition, causes of threat, resource optimization and approaches of successful history), and economic (economics of the forest, forest produce, ecosystem services, local and national interest, supportive organisation and source of funds required) at local level. The appropriate strategies for restoration and management programmes should be selected and implemented in such a way that the species composition, phytosociological structure, biodiversity, processes and functions of the restored forest all are close to the original forest and be capable to withstand over time [67, 76].

In general, the restoration may include passive protection of remnant vegetation and active acceleration of natural regeneration in a selected forest or other ecosystems [77]. Thus, restoration has two way of action *i.e.* passive and active. The passive restoration is based on the fact that the forests have high elasticity, resistance and self-repairing capacity which can help them to recover from any kind of disturbances provided they are kept away from further human interferences [76]. However, such a management action/recovery used enough time since these processes are too slow [78]. In this kind of restoration approach, the identification of causal elements is done first. This is followed by elimination or control of these elements to provide sufficient time for self-repairing [79, 80]. Although, it is a natural and well proved safest way of restoration in some areas, in certain conditions (high anthropogenic pressure; low self-repairing capacity due to low seed viability, seedling survival and growth, etc.) this passive way of restoration may not be successful. In such conditions, the active restoration strategies are generally utilised. In this approach of restoration, direct intervention, monitoring and evaluation are used to protect a targeted landscape, specific site, community and/or species. Plantation of native seedlings in scattered way and/or in patches is the most common and simplest way of active restoration [81-83].

The additions of nutrients in the soil, protection of planted seedlings/sapling for survival, judicious protection of disturbed sites are the other ways. Before the selection of any restoration strategy, it is important to know more about the local plants, association and their congregation [84, 85]. Additionally, it is also important to integrate the scientific principles with the community knowledge and its participation to extend the approach of restoration [86]. Keeping all these things in mind the present communication highlights the current key issues in the forest management and restoration and provides suggestions of theoretical and empirical framework for the management and restoration of Terai forest taking the account of local community's needs and expectations along with the regional changes.

Key issues in forest management and restoration

In the course of this study following issues regarding forest management and restoration have been identified in the Terai region of Uttar Pradesh:

Twenty four species of the total tree species of the region comes under the different categories of IUCN red list and require more attention towards conservation and restoration [4]. Besides these 24 tree species, *Indopiptadenia oudhensis* (Brandis) Brenan has also been found struggling with against natural and anthropogenic forces for its existence (Fig. 1). It is represented by countable numbers in the Bhabar zone of Suhelwa wildlife sanctuary, Balrampur [11, 87].

The Terai forests are the home of several indigenous species. These species have low ecological amplitude and narrow distribution range, resulting in the risk of their extinction. Although national parks (3 in numbers), wildlife sanctuaries (6 in numbers) and a tiger reserve

have already been declared by the Government, covering an area of about 4,534 km^2 [88]; there are large human settlements around the forest and, in many cases, penetrated the protected areas. The encroachment of the forest's land by the surrounding habitation has been reported since a long time back and the efforts taken so far to encounter these conditions not up to the mark [89-91]. This is the main reason behind illegal logging, lopping, grazing, and agriculture penetration, as well as, for human and wildlife conflicts (Figs. 2 and 3) [92-95].

Fig. 1. Destruction of *Indopiptadenia* community by riparian damage.

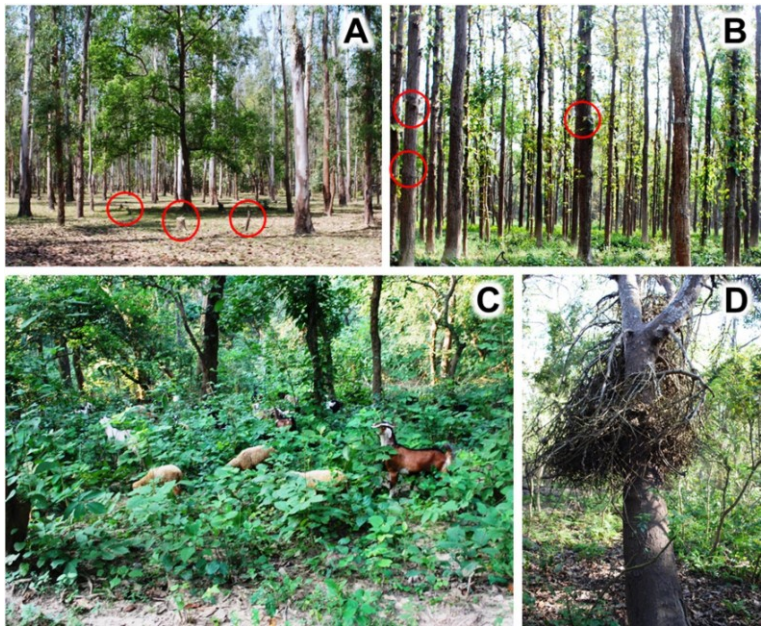

Fig. 2. Forest destruction through: A. Logging; B. Lopping; C and D. Grazing.
(D, *Ficus squamosa* - a grazing indicator tree).

The forests of the entire Terai region including protected areas are also facing the problem of fragmentation due to the presence of roads and railway tracks (Fig. 4). The problem of forest fragmentation by roads and railways and their adverse effects on biodiversity have already been reported from the different parts of the globe [96-102].

Most of the protected areas of the region are situated along the open boundary between India and Nepal and consequently influenced by the trans-boundary lopping and grazing problems (Fig. 5). The entire Terai region is also facing an enormous problem of illegal trade of not only timber wood but also of medicinally important plants, animal and their parts [103, 104]. Lack of awareness and education in the local tribes is another important reason behind the indiscriminate utilisation of forests products.

Fig. 3. Illegal penetration of agricultural lands in forest area.

Fig. 4. Habitat fragmentation through: A. Road; B. Railway.

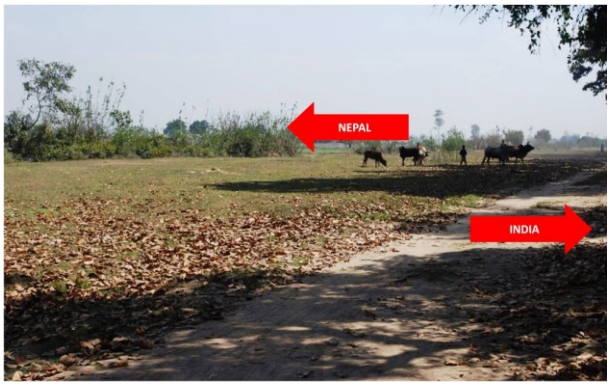

Fig. 5. Trans-boundary disturbances (logging, lopping and grazing).

Conclusions and recommendations

Based on our own observation together with an extensive survey of literature and other evidences, following suggestions emerge for restoration and management of the forest and species under risk in the region:

As the numbers of plant species are fighting for their existence in the Terai eco-region, there is an urgent need of management programmes for their conservation. For this purpose, the active restoration of species under highrisk of extinction through controlling zoo-anthropogenic pressure and accelerating their population growth by seed dispersal, seedling and/or sapling plantation and their monitoring may be adopted [68, 81, 83, 104-113].

As the *Indopiptadenia oudhensis* grows along the river banks on the gravelly-sandy soil, the floods and repairing damages destruct its already shrunken population. There should be some kind of construction or other mechanical support to the river banks to minimize extension of riparian damages. Change in policies such as the declaration of wildlife sanctuaries of the area into national parks may help forest conservation and rehabilitation of human population present within the territory of the protected area. Further development of the road and railways in the area was made only after adequate ecological mapping and the identification of environmentally fragile areas. Ecologically fragile areas should be kept away from habitat fragmentation. The high resolution remote sensing images may also play a very important role in the identification of forest fragmentation as well as the assessment of conservation practices [22, 114, 115].

Large scale trans-boundary lopping and grazing on the Indo-Nepal border need to be prevented and minimized. For this purpose, the responsible authorities from both the countries (India and Nepal) are continuously endeavouring in the direction of awareness generation against illegal trade of timber and non-timber products along with wild floral and faunal diversity among the local people and administrative authorities [104]. Although, several considerable steps have been taken in the direction of biodiversity conservation of the Terai eco-region, but still the illegal trans-boundary trade is a matter of great concern.

Thus there is an urgent need to generate awareness and uplift the education level of tribes living in and around the protected areas. Educating local people would help in understanding the need for sustainable use of forests is for the benefit of society in general and for their future generation in particular.

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References

[1] R.R. Rao, **Biodiversity in India** (Floristic Aspects), Bishen Singh Mahendra Pal Singh, Dehra Dun, 1994.

[2] R. De, **Management plan of Dudwa Tiger Reserve** (2000-2001 to 2009-2010), Uttar Pradesh: Wildlife Preservation Organization, Forest Department, Uttar Pradesh, India, 2001.

[3] R.P. Shukla, *Patterns of plant species diversity across Terai landscape in north-eastern Uttar Pradesh, India*, **Tropical Ecology, 50**(1), 2009, pp. 111-123.

[4] O. Bajpai, A. Kumar, A.K. Srivastava, A.K. Kushwaha, J. Pandey, L.B. Chaudhary, *Tree species of the Himalayan Terai region of Uttar Pradesh, India: a checklist*, **Check List, 11**(4), 2015, Article no. 1718.
[5] A. Husain, *Fauna of Rajaji Sanctuary (Distt. Saharanpur), Uttar Pradesh 2*, **Fish Cheetal, 16**(4), 1975, pp. 55-57.
[6] S. Pandey, J. Joshua, N.D. Rai, D. Mohan, G.S. Rawat, K. Sankar, M.V. Katti, D.V.S. Khati, A.J.T. *Johnsingh, Birds of Rajaji National Park, India*, **Forktail, 10**, 1994, pp. 105-114.
[7] A. Roy, *Study of Diversity of Mammals of Rajaji National Park (U.K.) in Relation to Ecoclimatic Changes Due to Anthropogenic Disturbances*, **Asian Resonance**, **5**(1), 2016, pp. 61-66.
[8] S.K. Pandey, R.P. Shukla, *Plant diversity and community patterns along the disturbance gradient in plantation forests of sal (Shorea robusta Gaertn.)*, **Current Science, 77**(6), 1999, pp. 814-818.
[9] K.P. Tripathi, B. Singh, *Species diversity and vegetation structure across various strata in natural and plantation forests in Katerniaghat Wildlife Sanctuary, North India*, **Tropical Ecology, 50**(1), 2009, pp. 191-200.
[10] O. Bajpai, A. Kumar, A.K. Mishra, N. Sahu, S.K. Behera, L.B. Chaudhary, *Phenological study of two dominant tree species in tropical moist deciduous forest from the northern India*, **International Journal of Botany, 8**(2), 2012, pp. 66-72.
[11] O. Bajpai, A.K. Kushwaha, A.K. Srivastava, J. Pandey, L.B. Chaudhary, *Phytosociological Status of a Monotypic Genus Indopiptadenia: A Near Threatened Tree from the Terai-Bhabar Region of Central Himalaya*, **Research Journal of Forestry, 9**(2), 2015, pp. 35-47.
[12] A. Kumar, O. Bajpai, A.K. Mishra, N. Sahu, S.K. Behera, S.S. Bargali, L.B. Chaudhary, *A checklist of the flowering plants of Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India*, **Journal of Threatened Taxa, 7**(7), 2015, pp. 7309-7408.
[13] N. Myers, *The biodiversity challenge: expanded hotspot analysis*, **Environmentalist, 10**, 1990, pp. 243-256.
[14] D. Pearce, *Valuing biological diversity: issues and overview*, **Valuation of biodiversity benefits**, Selected Studies, OECD, Paris, 2001.
[15] R.T. Woodward, Y.S. Wui, The economic value of wetland services: a meta-analysis. **Ecological Economics 37**, 2001, pp. 257-270.
[16] R. Badola, S.A. Hussain, B.K. Mishra, B. Konthoujam, S. Thapliyal, M. Dhakate, *An assessment of ecosystem services of Corbett Tiger Reserve, India*, **Environmentalist, 30**, 2010, pp. 320-329.
[17] P.B. Shah, *Watershed degradation and its socio-economic impacts using RS and GIS: a case study of Trijuga watershed, Nepal*, **M.Sc. Dissertation**, NR 96-20, AIT, Bangkok, Thailand, 1996.
[18] N. Dudley, S. Stolton, *The role of forested protected areas in supplying drinking water to the world's biggest cities,* **The Urbane Imperative**, (Editor: T. Trzyna), California Institute of Public Affairs, Sacramento, 2005.
[19] T.R. Nisbet, H. Thomas, *The role of woodland in flood control: A landscape perspective*, **Proceedings of the 14th annual IALE (UK) Conference on Water and the Landscape,** (Editors: B. Davies and S. Thompson), Oxford, UK, 2006, pp. 118-125.
[20] K. Moin, *Floods in Bihar: Management and Control*, **Hazard Ecology: Approaches and Techniques,** (Editor: B.W. Pandey), Mittal Publication, New Delhi, India, 2010, pp. 337-346.
[21] S. Chakravarty, S.K. Ghosh, C.P. Suresh, A.N. Dey, G. Shukla, *Deforestation: Causes, Effects and Control Strategies,* **Global Perspectives on Sustainable Forest Management,** (Editor: O.C. Akais), InTech Publication, Croatia, European Union, 2012, pp. 3-28.

[22] N. Midha, P.K. Mathur, *Assessment of forest fragmentation in the conservation priority Dudhwa landscape, India using FRAGSTATS computed class level metrics*, **Journal of the Indian Society of Remote Sensing, 38**, 2010, pp. 487-500.
[23] S.N. Prasad, T.V. Ramachandra, N. Ahalya, T. Sengupta, A. Kumar, A.K. Tiwari, V.S. Vijayan, L. Vijayan, *Conservation of wetlands of India - a review*, **Tropical Ecology, 43**(1), 2002, pp. 173-186.
[24] S. Jha, *Status and Conservation of Lowland Terai Wetlands in Nepal*, **Our Nature, 6**(1), 2008, pp. 67-77.
[25] R.A. Vaidya, *The Role of Water Storage in Adaptation to Climate Change in the HKH Region,* **Sustainable Mountain Development**, **56**, 2009, pp. 10-13.
[26] R. Singh, J.D.S. Negi, *Biomass prediction and distribution of organic matter in natural Cinnamomum camphora stand*, **Indian Forester, 123**, 1997, pp. 1161-1170.
[27] A.K. Lal, P.P. Singh, *Economic worth of carbon stored in above ground biomass of India's Forests*, **Indian Forester, 129**(7), 2003, pp. 874-880.
[28] T.P. Upadhyay, P.L. Sankhayan, B. Solberg, *A review of carbon sequestration dynamics in the Himalayan region as a function of land-use change and forest/soil degradation with special reference to Nepal*. **Agriculture, Ecosystems and Environment, 105**(3), 2005, pp. 449-465.
[29] E. Tvinnereim, K. Roine, C. Heimdal, **Carbon 2009 - Emission Trading Coming Home. Point Carbon,** Oslo, 2009, p. 48.
[30] H.P. Bhatnagar, *Soils from different quality Sal forest of UP India*, **Tropical Ecology, 6**, 1965, pp. 56-62.
[31] R.P.C. Morgan, **Soil erosion and conservation**, Longman Scientific and Technical, Harlow, 1986.
[32] S.K. Banerjee, S. Nath, B. Singh, P.K. Das, S.K. Gangopadhyay, *Soil characteristics under Sal (Shorea robusta) in Terai region of the north-eastern Himalayas (India)*, **Indian Forester, 115**(9), 1989, pp. 626-634.
[33] P.P. Motavalli, C.A. Palm, W.J. Parton, E.T. Elliott, S.D. Frey, *Soil pH and organic C dynamics in tropical forest soils: Evidence from laboratory and simulation studies*, **Soil Biology and Biochemistry, 27**(12), 1995, pp. 1589-1599.
[34] S.H. Rashid, M.M. Rahman, A.B.M. HossainEnayet, *Ecological studies on the relationship between soil properties and dominant undergrowth species of Chandra Sal Forest at Gazipur, Bangladesh*, **Ecoprint, 4**(1), 1997, pp. 9-14.
[35] L.A. Bruijnzeel, *Soil chemical changes after tropical forest disturbance and conversion: The hydrological perspective*, **Soils of Tropical Forest Ecosystems: Characteristics, Ecology and Management**, (Editors: A. Schulte and D. Ruhiyat), Springer, New York, USA, (1998), pp. 45-61.
[36] L.C. Brouwer, H.T. Riezebos, *Nutrient dynamics in intact and logged tropical rain forest in Guyana,* **Soils of Tropical Forest Ecosystems: Characteristics, Ecology and Management,** (Editors: A. Schulte and D. Ruhiyat), Springer, New York, USA, 1998, pp. 73-86.
[37] M.U.F. Kirschboum, B. Harms, N.J. Mathers, R.C. Dalal, *Soil carbon and nitrogen changes after clearing mulga (Acacia aneura) vegetation in Queensland, Australia: Observation, simulations and scenario analysis*, **Soil Biology and Biochemistry, 40**, 2008, pp. 392-405.
[38] J. Vijayanathan, A.Z. Yahya, A. Yaacob, A.S. Kassim, S.W. Chik, *Impact of Thinning of Acacia Mangium Plantation on Soil Chemical Properties*, **Malaysian Journal of Soil Science, 15**, 2011, pp. 75-85.
[39] P. Iamtrakul, K. Teknomo, K. Hokao, *Public park valuation using travel cost method*, **Proceedings of East Asia Society for Transportation Studies, 5**, 2005, pp. 1249–1264.
[40] T. Kuuluvainen, *Disturbance Dynamics in Boreal Forests: Defi ning the Ecological Basis of Restoration and Management of Biodiversity*, **Silva Fennica, 36**(1), 2002, pp. 5-11.

[41] S.T.A. Pickett, P.S. White, (Eds.), **The Ecology of Natural Disturbance and Patch Dynamics**, Academic Press, New York, 1985.
[42] T. Kuuluvainen, *Gap disturbance, ground microtopography, and the regeneration dynamics of boreal coniferous forests in Finland, a review*, **Annales Zoologici Fennici, 31**, 1994, pp. 35-51.
[43] S.T.A. Pickett, R.S. Ostfeld, M. Shachak, G.E. Likens, **The Ecological Basis of Conservation: Heterogeneity, Ecosystems, and Biodiversity**, Chapham & Hall, New York, 1997.
[44] Y. Bergeron, O. Engelmark, B. Harvey, H. Morin, L. Sirois, *Key issues in disturbance dynamics in boreal forests: Introduction*, **Journal of Vegetation Science, 9**, 2009, pp. 464-468.
[45] O. Bajpai, A. Kumar, A.K. Mishra, N. Sahu, J. Pandey, S.K. Behera, L.B. Chaudhary, *Recongregation of tree species of Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India*, **Journal of Biodiversity and Environmental Sciences, 2**(12), 2012, pp. 24-40.
[46] R.K. *Gupta Impact of human influences on the vegetation of the Western Himalaya*, **Plant Ecology, 37**, 2004, pp. 111-118.
[47] N.L. Boivina, M.A. Zederc, D.Q. Fullere, A. Crowtherf, G. Larsong, J.M. Erlandsonh, T. Denhami, M.D. Petraglia, *Ecological consequences of human niche construction: Examining long-term anthropogenic shaping of global species distributions*, **PNAS, 113**(23), 2016, pp. 6388-6396.
[48] P.-A. Esseen, B. Ehnström, L. Ericson, K. Sjöberg, *Boreal forests*, **Ecological Bulletins, 46**, 1997, pp. 16-47.
[49] MEA, **Millenium Ecosystem Assessment**, Ecosystems and Human Well-Being Biodiveristy Synthesis, Island Press, Washington, DC, USA, 2005.
[50] J.M. Kneitel, J.M. Chase, *Disturbance, predator, and resource interactions alter container community composition*, **Ecology, 85**, 2004, pp. 2088-2093.
[51] Z.A. Malik, R. Pandey, A.B. Bhatt, *Anthropogenic disturbances and their impact on vegetation in Western Himalaya, India*, **Journal of Mountain Science, 13**(1), 2016, pp. 69-82.
[52] A.B. Cunningham, **Applied Ethnobotany: People, Wild Plant Use and Conservation**, **People and Plants Conversation Manual**, Earthscan, London, 2001.
[53] A.V. Hoang, P. Baas, P.J.A. Keβler, *Uses and Conservation of Plant Species in a National Park - A Case Study of Ben En, Vietnam*, **Economic Botany, 62**(4), 2008, pp. 574-593.
[54] G. Bodeker, C. van'tKlooster, E. Weisbord, *Prunus africana (Hook.f.) Kalkman: The Overexploitation of a Medicinal Plant Species and Its Legal Context*, **Journal of Alternative and Complementary Medicine, 20**(11), 2014, pp. 810-822.
[55] A. Kumar, J. Ram, Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, central Himalaya. **Biodiversity and Conservation, 14**, 2005, pp. 309-331.
[56] G. Dutta, A. Devi, *Impact of lopping on tree species of tropical Indian forests*, **Tropical Plant Research, 2**(1), 2015, pp. 1-4.
[57] D.G. Milchunas, W.K. Lauenroth, *Quantitative effects of grazing on vegetation and soils over a global range of environments*, **Ecological Monographs, 63**, 1993, pp. 327-366.
[58] M. Krzic, R.F. Newman, C. Trethewey, C.E. Bulmer, B.K. Chapman, *Cattle grazing effects on the plant species composition and soil compaction on rehabilitated forest landings in central interior British Columbia*, **Journal of Soil and Water Conservation, 61**, 2006, pp. 137-144.
[59] M. Hanief, A. Bidalia, A. Meena, K.S. Rao, *Natural regeneration dynamics of dominant tree species along an altitudinal gradient in three different forest covers of Darhal watershed in north western Himalaya (Kashmir), India*, **Tropical Plant Research, 3**(2), 2016, pp. 253-262.

[60] J.S. Singh, *Man and forest interactions in Central Himalaya,* **Himalayan Environment and Development Problems and Perspective,** (Editors: J.S. Singh and S.P. Singh), Gyanodaya Prakashan, Nainital, India, 1992, pp. 51-80.
[61] Jr. G.E. Heilman, J.R. Strittholt, N.C. Slosser, D.A. Dominick, *Forest fragmentation of the conterminous United States: Assessing forest intactness through road density and spatial characteristics*, **BioScience, 52**(5), 2002, pp. 411-422.
[62] F.D. Dami, G.S. Mwansat, S.A. Manu, *The effects of forest fragmentation on species richness on the Obudu Plateau, south-eastern Nigeria*, **African Journal of Ecology, 51**(1), 2012, pp. 32-36.
[63] R.F. Noss, A. Cooperrider, **Saving Nature's Legacy,** Island Press, Washington DC, 1994.
[64] J.S. Denslow, S.J. Dewalt, *Exotic plant invasions in tropical forests: patterns and hypotheses,* **Tropical Forest Community Ecology,** (Editors: W.P. Carson and S.A. Schnitzer), Wiley-Blackwell, Oxford, UK, 2008.
[65] K.S. Dogra, S.K. Sood, P.K. Dobhal, S. Sharma, *Alien plant invasion and their impact on indigenous species diversity at global scale: A review*, **Journal of Ecology and The Natural Environment, 2**(9), 2010, pp. 175-186.
[66] R.J. Morris, *Anthropogenic impacts on tropical forest biodiversity: a network structure and ecosystem functioning perspective*, **Philosophical Transactions of the Royal Society of London, Series B, 365**(1558), 2010, pp. 3709-3718.
[67] A.D. Dominick, A. Martin, R. Spivak, T. Schulke, B. Bird, M. Criley, C. van Daalen, J. Kreilick, R. Brown, G. Aplet, *A Citizen's Call for Ecological Forest Restoration: Forest Restoration Principles and Criteria*, **Restoration Ecology, 21**(1), 2003, pp. 14-23.
[68] D. Lamb, P.D. Erskine, J.A. Parrotta, *Restoration of degraded tropical forest landscapes*, **Science, 310**, 2005, pp. 1628-1632.
[69] D. Lamb, **Regreening the Bare Hills**, Springer, 2011, p. 547.
[70] T. Ricketts, E. Dinerstein, D. Olson, C. Loucks, W. Eichbaum, D. DellaSala, K. Kavanagh, P. Hedao, P. Hurley, K. Carney, R. Abell, S. Walters, **A Conservation Assessment of the Terrestrial Ecoregions of North America**, Island Press, Washington, DC, 1999.
[71] D. Pimentel, L. Westra, R. Noss, (Eds.), **Ecological Integrity: Integrating Environment, Conservation, and Health**, Island Press, Washington, DC, 2001.
[72] B. Singh, S.K. Borthakur, *Forest issues and challenges in protected area management: A case study from Himalayan Nokrek national park and biosphere reserve, India*, **International Journal of Conservation Science, 6**(2), 2015, pp. 233-252.
[73] * * *, Society for Ecological Restoration International, Science and Policy Working Group, **The Society for Ecological Restoration International Primer on Ecological Restoration**, SER, Tucson, AZ, 2004.
[74] D. Morrison, *Landscape restoration in response to previous disturbance*, **Landscape Heterogeneity and Disturbance**, (Editor: M.G. Turner), Springer-Verlag, New York, 1990, pp. 159-172.
[75] J.G. Kairo, F. Dahdouh-Guebas, J. Bosire, N. Koedam, *Restoration and management of mangrove systems - a lesson for and from the East African region*, **South African Journal of Botany, 67**, 2001, pp. 383-389.
[76] * * *, **Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Tropical Forests**, ITTO Policy Development Series No 13, International Tropical Timber Organization, 2002, pp. 23-31.
[77] J.G. David, B.D. Patrick, **Assisted Natural Regeneration: An Overview**. http://www.fao.org/docrep/004/ad466e/ad466e03.htm. (2011).
[78] J.S. Lwanga, *Forest succession in Kibale national park, Uganda: Implications for forest restoration and management*, **African Journal of Ecology, 41**, 2003, pp. 9-22.
[79] J.B. Kauffman, R.L. Beschta, N. Otting, D. Lytjen, *An ecological perspective of riparian and stream restoration in the western United States*, **Fisheries, 22**(5), 1997, pp. 12-24.

[80] National Research Council, **Environmental Issues in Pacific North-West Forest Management**, National Academy Press, Washington, DC, 1999.
[81] S. Elliotta, P. Navakitbumrunga, C. Kuaraka, S. Zangkuma, V. Anusarnsunthorna, D. Blakesley, *Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance*, **Forest Ecology and Management, 184**, 2003, pp. 177-191.
[82] S. McNamara, D.V. Tinh, P.D. Erskine, D. Lamb, D. Yates, S. Brown, *Rehabilitating degraded forest land in central Vietnam with mixed native species plantings*, **Forest Ecology and Management, 233**(2–3), 2006, pp. 358-365.
[83] L. Yang, R. Sailesh, D.H. Rhett, X. Jianchu, O. Xiaokun, M. Xuelan, H. Jun, *Selection of Native Tree Species for Subtropical Forest Restoration in Southwest China*, **PLoS ONE, 12**(1), 2017, Article no. e0170418.
[84] R. Daubenmire, **Plants and Environment**, Harper and Row, New York, 1968.
[85] R.T. Brown, J.K. Agee, J.F. Franklin, *Forest restoration and fire: Principles in the context of place*, **Conservation Biology, 18**(4), 2004, pp. 903-912.
[86] E.S. Higgs, *What is good ecological restoration*? **Conservation Biology, 11**, 1997, pp. 338-348.
[87] O. Bajpai, A.K. Srivastava, A.K. Kushwaha, L.B. Chaudhary, *Taxonomy of a monotypic genus Indopiptadenia (Leguminosae-Mimosoideae)*, **Phytotaxa, 164**(2), 2014, pp. 61-78.
[88] * * *, **Annual Report**, Ministry of Environment and Forest, Govt. of India, New Delhi, 2005.
[89] E. Dinerstein, *An ecological survey of the royal Karnali-Bardia Wildlife Reserve, Nepal, Part I: Vegetation, modifying factors, and successional relationships*, **Biological Conservation, 15**(2), 1979, pp. 127-150.
[90] O. Rautiainena, J. Suoheimo, *Natural regeneration potential and early development of Shorea robusta Gaertn. f. forest after regeneration felling in the Bhabar-Terai zone in Nepal*, **Forest Ecology and Management, 92**(1-3), 1997, pp. 243-251.
[91] H. Nagendra, Y. *Gokhale, Management Regimes, Property Rights, and Forest Biodiversity in Nepal and India*, **Environmental Management, 41**(5), 2008, pp. 719-733.
[92] R. Shrestha, S.B. Bajracharya, N.M.B. Pradhan, **A Case Study on Human-Wildlife Conflict in Nepal (With Particular Reference to Humanelephant Conflict in Eastern and Western Terai regions)**, Species Program WWF International, Nepal, 2007.
[93] R. DeFries, K.K. Karantha, S. Pareeth, *Interactions between protected areas and their surroundings in human-dominated tropical landscapes*, **Biological Conservation, 143**(12), 2010, pp. 2870-2880.
[94] A. Harihar, B. Pandav, *Influence of Connectivity, Wild Prey and Disturbance on Occupancy of Tigers in the Human-Dominated Western Terai Arc Landscape*, **PLoS ONE, 7**(7), 2012, Article no. e40105.
[95] A. Harihar, B. Pandav, D.C. MacMillan, *Identifying realistic recovery targets and conservation actions for tigers in a human-dominated landscape using spatially explicit densities of wild prey and their determinants*, **Diversity and Distributions, 10**(5), 2014, pp. 567-578.
[96] A. Andrews, *Fragmentation of habitat by roads and utility corridors: A review*, **Australian Journal of Zoology, 26**, 1990, pp. 130-141.
[97] R.T.T. Forman, **Land Mosaics: The Ecology of Landscapes and Regions**, Cambridge University Press, Cambridge, 1995.
[98] K. Canters, A. Piepers, A. Hendriks-Heersma, *Habitat Fragmentation, Infrastructure and the Role of Ecological Engineering,* **Proceedings of the International Conference on Habitat Fragmentation and Infrastructure in Maastricht & DenHague** 1995, Delft, The Netherlands: Ministry of Transport, Public Works and Water Management, Road and Hydraulic Engineering division, 1997.

[99] R.T. Forman, L.E. Alexander, *Roads and their major ecological effects*, **Annual Review of Ecology, Evolution, and Systematics, 29**, 1998, pp. 207-231.
[100] S.C. Trombulak, C.A. Frissell, Review of ecological effects of roads on terrestrial and aquatic communities. **Conservation Biology, 14**, 2000, pp. 18-30.
[101] R. Joshi, R. Singh, *Asian Elephants are Losing Their Seasonal Traditional Movement Tracks: A Decade of Study in and Around the Rajaji National Park, India*, **Gajah, 27**, 2007, pp. 15-26.
[102] G. Areendran, M. Raj, K. Raj, S. Mazumdar, J. Forest, M. Munsi, E. Wikramanayake, *Modeling Impact of Economic Development Projects on Tiger Conservation Landscape - A Case Study from Nilgiris, India*, **Asian Journal of Geoinformatics, 12**(1), 2012, pp. 1-7.
[103] S. Oldfield, **The Trade in Wildlife: Regulation for Conservation**, Earthscan Publications Ltd., London, UK, 2003, p. 16.
[104] R.L. Semwal, **The Terai Arc Landscape in India: Securing Protected Areas in the Face of Global Change**, **Forests & Biodiversity Conservation Programme**, World Wide Fund for Nature, New Delhi, India, 2005.
[105] J. Kerby, S. Elliott, J.F. Maxwell, D. Blakesley, V. Anusarnsunthorn, (Eds.), **Tree Seeds and Seedlings for Restoring Forests in Northern Thailand**. Forest Restoration Research Unit, Biology Department, Science Faculty, Chiang Mai University, Thailand, 2000.
[106] C.I. Millar, N.L. Stephenson, S.L. Stephens, *Climate change and forests of the future: managing in the face of uncertainty*, **Ecological Applications, 17**, 2007, pp. 2145-2151.
[107] S.J. Doust, P.D. Erskine, D. Lamb, *Restoring rainforest species by direct seeding: tree seedling establishment and growth performance on degraded land in the wet tropics of Australia*, **Forest Ecology and Management, 256**, 2008, pp. 1178-1188.
[108] T. Raman, D. Mudappa, V. Kapoor, *Restoring rainforest fragments: Survival of mixed-native species seedlings under contrasting site conditions in the Western Ghats, India*, **Restoration Ecology, 17**(1), 2009, pp. 137-147.
[109] K.D. Holl, R.A. Zahawi, R.J. Cole, R. Ostertag, S. Cordell, *Planting seedlings in tree islands versus plantations as a large-scale tropical forest restoration strategy*, **Restoration Ecology, 19**, 2011, pp. 470-479.
[110] R. Schröder, R. Prasse, *Cultivation and hybridization alter the germination behavior of native plants used in revegetation and restoration*, **Restoration Ecology, 21**, 2013, pp. 793-800.
[111] P.G. Scowcroft, J.T. Yeh, *Passive restoration augments active restoration in deforested landscapes: the role of root suckering adjacent to planted stands of Acacia koa*, **Forest Ecology and Management, 305**, 2013, pp. 138-145.
[112] J.A. Stanturf, B.J. Palik, R.K. Dumroese, *Contemporary forest restoration: A review emphasizing function*, **Forest Ecology and Management, 331**, 2014, pp. 292-323.
[113] U.K. Sen, *Assessing the Social, Ecological and Economic Impact on Conservation Activities Within Human-Modified Landscapes: A Case Study In Jhargram District of West Bengal, India,* **International Journal of Conservation Science, 9**(2), 2018, pp. 319-336.
[114] L.A.B.J. Jorge, G.J. Garcia, *A study of habitat fragmentation in Southeastern Brazil using Remote Sensing and Geographic Information Systems (GIS)*, **Forest Ecology and Management, 98**, 1997, pp. 35-47.
[115] A. Miyamoto, M. Sano, *The influence of forest management on landscape structure in the cooltemperate forest region of central Japan*, **Landscape and Urban Planning, 86**, 2008, pp. 248-256.

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